Appendix C

Road Density Calculation for the Thunder Basin National Grassland

Introduction and Method Rationale

As detailed in the body of this document, roads and their use can have a wide variety of impacts on the physical, biological, and social environment. These effects are generally described with reference to their specific impacts on a given resource – i.e. road associated effects on sediment delivery at stream crossings, dispersal and establishment of non-native invasive species along road corridors, disturbance of grouse lek sites, etc. Typically, these impacts are studied at the individual road, stream, species or habitat type level.

However, for the purposes of road *system* planning, an additional measure is required that reflects the relative influence of the road system on a landscape level. The most common measure used for this purpose is road density.

Road density calculations can be performed in several different ways, each with a slightly different outcome that may be more or less appropriate depending on the resource being addressed. Two general types of GIS-based calculations of road density were performed for this analysis.

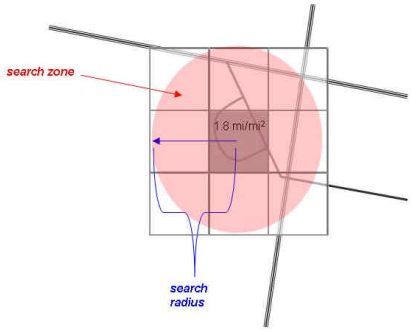
The first, considered the simplest of road density calculations, involved the calculation of the number road miles within a specified boundary, divided by the square mile area within the boundary. This method is commonly used to assess the potential influence of roads on hydrologic processes, where impacts such as increases in sediment production and changes in drainage patterns have effects that are most appropriately addressed within the watershed in which they occur.

For addressing landscape level hydrologic concerns in this analysis, average road density was calculated for each of the 24 5^{th} level watersheds on the TBNG (miles of road in 5^{th} level HUC ÷ Square mile area of 5^{th} Level HUC). The average watershed road densities were then divided into three relative groups representing low (less than 1.6 mi/mi^2), moderate (1.6 mi/mi^2 to 2.0 mi/mi^2), and high average road densities (greater than 2.0 mi/mi^2). The results of this calculation are presented in **Figure C-2**.

The second type of road density calculation performed allows for the assessment of road density as it varies across the landscape. For this method, road density is evaluated for each square cell (of chosen size) within a grid covering the entire landscape. This method allows for the display of the *distribution* of road densities across the landscape (rather than the calculation of an average density across a broad area).

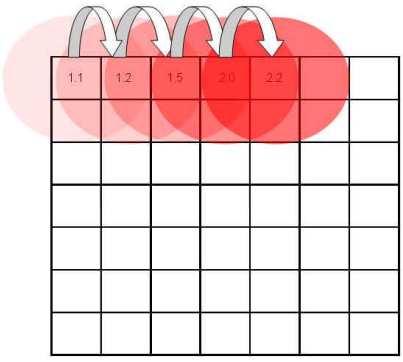
For the purposes of this analysis, a modified version of the calculation describe above was used. This modified method involved assigning a road density value to each grid cell based on the a density calculation that is centered on the midpoint of the cell, but greater than the grid cell itself. The size of this area was defined by a "search radius", which defined the zone over which the road mileage would be counted and then divided by the square mile area of the search zone.

The following graphic illustrates this principal:



In this example, a 9 cell grid is placed over a small group of roads. The search radius (the red arrow) for the central cell of the grid is set at 1.5 times the width of each grid cell. This results in a total search area (the red circle) that is over 7 times the area of the central grid cell. Road miles falling within the circle are tallied and divided by the total search area. This road density value is then assigned to the central cell.

On a landscape level, this calculation continues across the entire road system/ landscape. The program calculates the road density for a search area, assigns the grid cell the density value, and moves on the next adjacent cell, repeating the process until each grid cell is given a value. This process is depicted in the following graphic.



This method of road density calculation is often referred to as a "moving window" analysis due to the cell by cell movement of the overlapping search area 'windows' across the analysis grid. As described previously, it is commonly used by biologists to assess wildlife/road system interactions on a landscape scale. With this method, local cell to cell variations in road density are 'smoothed' based on conditions in adjacent areas. The resultant road density grid allows for a more holistic evaluation of the road density of an area, rather than the density of an individual grid cell. This is especially useful for addressing effects on animals with larger home ranges and diverse habitat use patterns, where microscale variations in habitat are not as important as landscape level changes.

For this analysis, road density was calculated for each 1 mile square cell in a grid covering the entire administrative boundary of the TBNG. The search radius for the moving window was set at 1.5 miles, resulting in a search area that included much of the area of the adjacent grid cells (See graphic top left of page). The result of this road density calculation is provided in **Figure C-3**.

The road density grid described above was further used to address conditions on an individual road level. This was done for the purposes of evaluating the road density conditions through which an individual USFS maintenance level 3 road passed. This information was used as one indicator of the potential risk use of this road posed to TBNG wildlife (See Chapter 5 of this RAP). For example, if a maintenance level 3 road was primarily found in an area of high road density *and* high density of known wildlife concerns (known lek sites,

sensitive species occurrences, prairie dog habitat, etc.) this road would be ranked as 'high' for its potential to pose risk to TBNG wildlife resources.

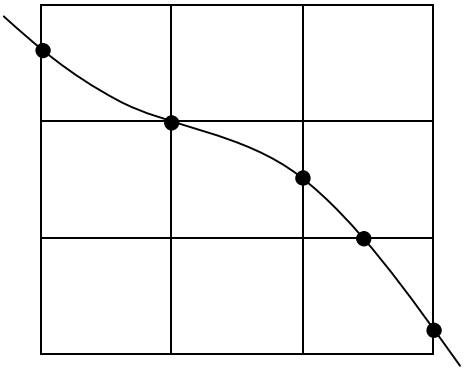
In order to develop this road-specific assessment of area road density, the road density grid displayed in **Figure C-2** was modified. Road densities ranged in this grid from 0 to ~ 6 mi/mi^2. For GIS purposes, to extract road density information from this layer and attribute it to each maintenance level 3 road, the grid needed to be converted from a grid to a shapefile.

The following is the specific GIS process performed for this purpose:

For the conversion, the grid was reclassified, grouping road densities into one of 24 classes (0.25 mile bins: Bin 1 = 0 to 0.25 mi/mi^2, Bin 2 = 0.25 to 0.50 mi/mi^2, Bin 3 = 0.75 to 1.00 mi/mi^2, etc.).

This process yielded a shapefile (non-generalized boundaries), with each polygon within assigned an index value representing one of the 24 road density categories (1, 2, 3, etc.) based on the road density grid. These index values were then back-calculated to represent the calculated road density. This was done by assigning each index number the road density associated with the midpoint of its bin. For example, index # 1 represented road densities from 0.00 to 0.25 mi/mi^2, and was assigned a value of 0.125 mi/mi^2; index #2 represented road densities from 0.25 to 0.50 mi/mi^2, and was assigned a value of 0.375 mi/mi^2; etc.

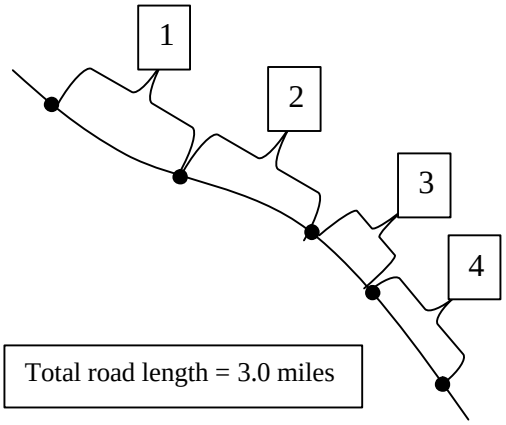
The USFS maintenance level 3 road system was then intersected with this road density shapefile. The following graphic depicts this process.



The intersection process partitions the road as it crosses through different road density cells. Each of these segments is attributed with the road density estimate of the area underlying the road layer.

Knowing the area road density for each segment and the segment length, a weighted average area road density for each road can be computed. This calculation essentially represents the weighted average road density of all of the *areas* through which the road traverses. The graphic on the next page depicts how this was calculated.

For the purpose of this analysis, weighted average area road densities were divided into three relative groups representing low (less than 2 mi/mi^2), moderate (2.0 mi/mi^2 to 2.5 mi/mi^2), and high weighted average area road densities (greater than 2.5 mi/mi^2). The distribution of mileage within these categories was one of the criteria used for assessing the potential risks individual roads and their use may pose to TBNG wildlife (see Chapter 5).



Segment 1	Segment 2	Segment 3	Segment 4
Area road density 1.1 mi/mi^2	Area road density 1.5 mi/mi^2	Area road density 2.0 mi/mi^2	Area road density 2.2 mi/mi^2
Segment Length 1.0 mi	Segment Length 1.0 mi	Segment Length 0.5 mi	Segment Length 0.5 mi

Weighted Area Road Density = S {(Seg. "X" (Segment Length/Total Road Length) * Area road density for segment)}

= S {((1.0/3.0)*1.1) + (1.0/3.0)*1.5) + (0.5/3.0)*2.0) + (0.5/3.0)*2.2)}

= 0.37 + 0.50 + 0.33 + 0.37 = **1.57 mi/mi^2**

This calculation was performed for each of the 69 maintenance USFS maintenance level 3 roads covered in Chapter 5 of this RAP.

Road Data Preparation:

Three GIS-based road layers of varying accuracy and completeness are available for the lands and region surrounding the TBNG.

1. The USFS road layer with associated INFRA data is the most accurate layer for lands on the TBNG. However, this layer is incomplete outside of lands that are managed by the USFS. Thus, it was only used for assessing road density on USFS managed lands.
2. For lands outside of federal ownership, but within the administrative boundary of the TBNG, a second road layer derived from USGS topographic quads and modified by the USFS was used.
3. US Census Bureau TIGER line files were used for road density calculations outside of the administrative boundary of the TBNG.

These three road layers were clipped to the boundary for which they were most accurate and then combined into one road layer for assessing road density. The following map depicts the compilation of road layers by there boundaries (**Figure C-3**).

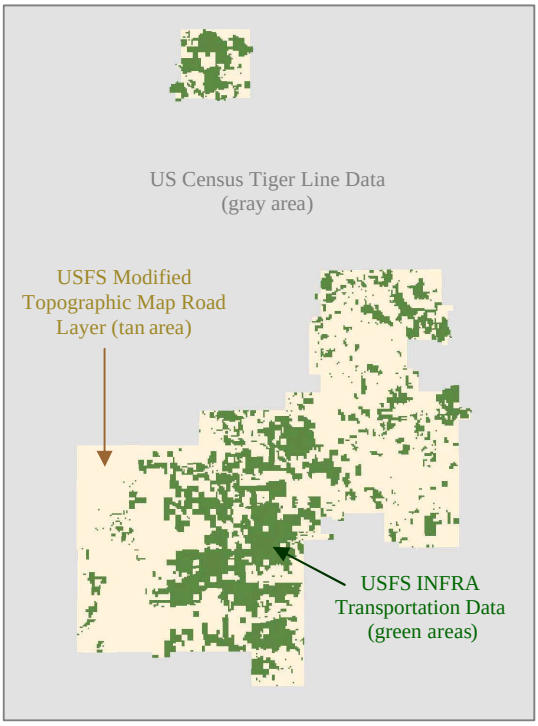


Figure C-3. Road data use by land area

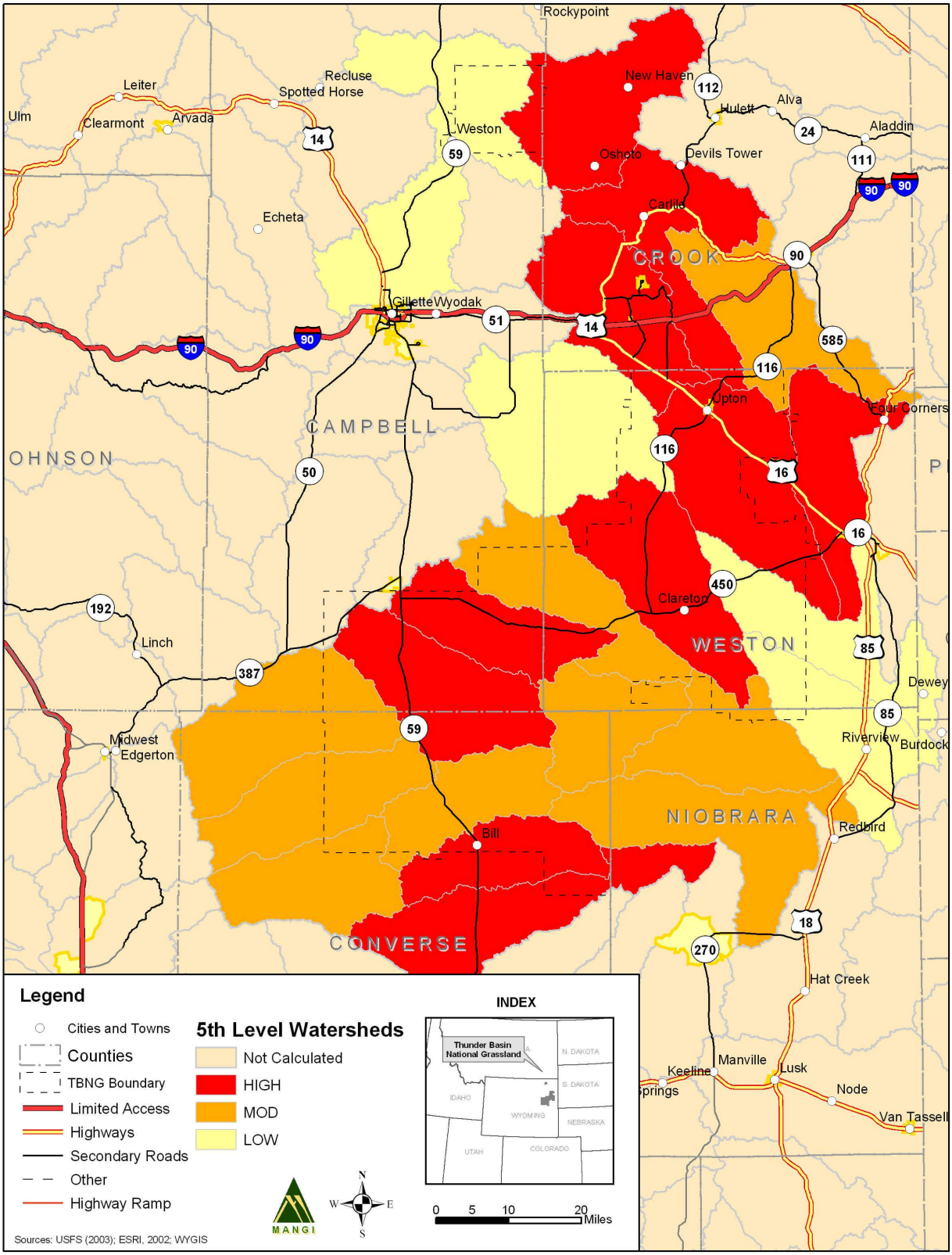


Figure C-1 Road Density by Fifth Level Watershed

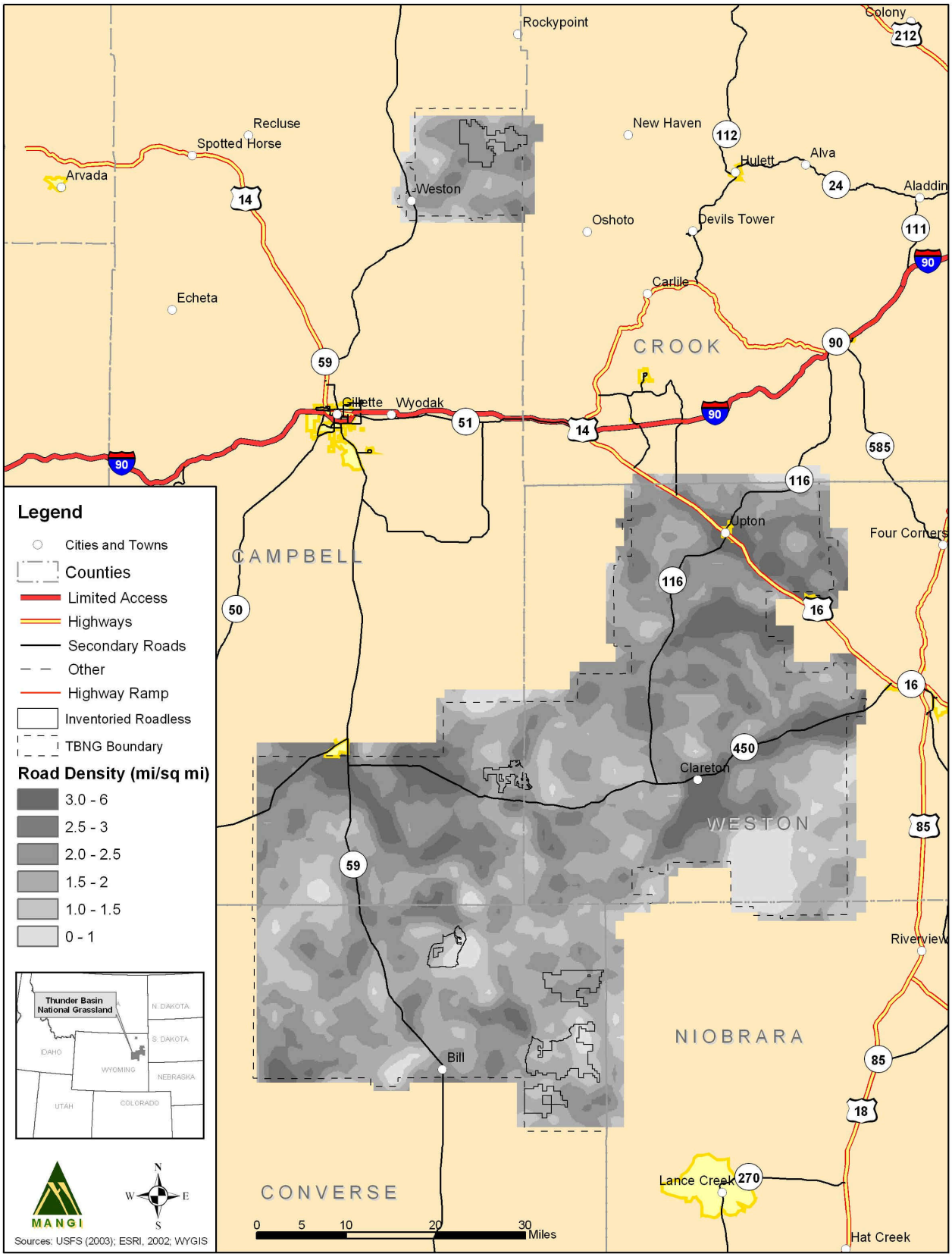


Figure C-3 Road Density Across the Thunder Basin National Grassland